

Electron Cooling for Low-Energy RHIC Operation

Update

October 22, 2009

Outline

Brief update on:

- **Recycler cooler and its possible location in RHIC tunnel**
- **Preliminary cost estimate**
- **Work scope**
- **Summary of FNAL visit**
- **Needed Recycler's cooler modifications**
- **Timeline and future plans**

More details on specific topics to be discussed in regular meetings to follow.

WHITE PAPER-V.1**Parameters and design issues of
Electron Cooler for Low-Energy RHIC program**

Collider-Accelerator Department, BNL

3

The goal of this document is to initialize progress towards design of Electron Cooler for cooling of heavy ion in RHIC at energies below nominal injection energy. This is a working document and material will be replaced on continues bases. Most numbers are preliminary and will be corrected as design proceeds. This is not a design document and intended for discussion purpose only.

Table of Contents

1. Overview
2. Electron cooler parameters
3. Electron beam transport
4. Cooling section
5. RHIC lattice
6. Layout in RHIC tunnel
7. Outstanding engineering questions
8. Outstanding physics questions
9. Milestones
10. Work scope
11. Transport and installation topics
12. References

Appendix (Fermilab Recycler Electron Cooler):

- A1. Recycler cooler layout
- A2. Pelletron
- A3. Devices
- A4. Diagnostics
- A5. Controls
- A6. Cooling section
- A7. Utilities
- A8. Operational aspects

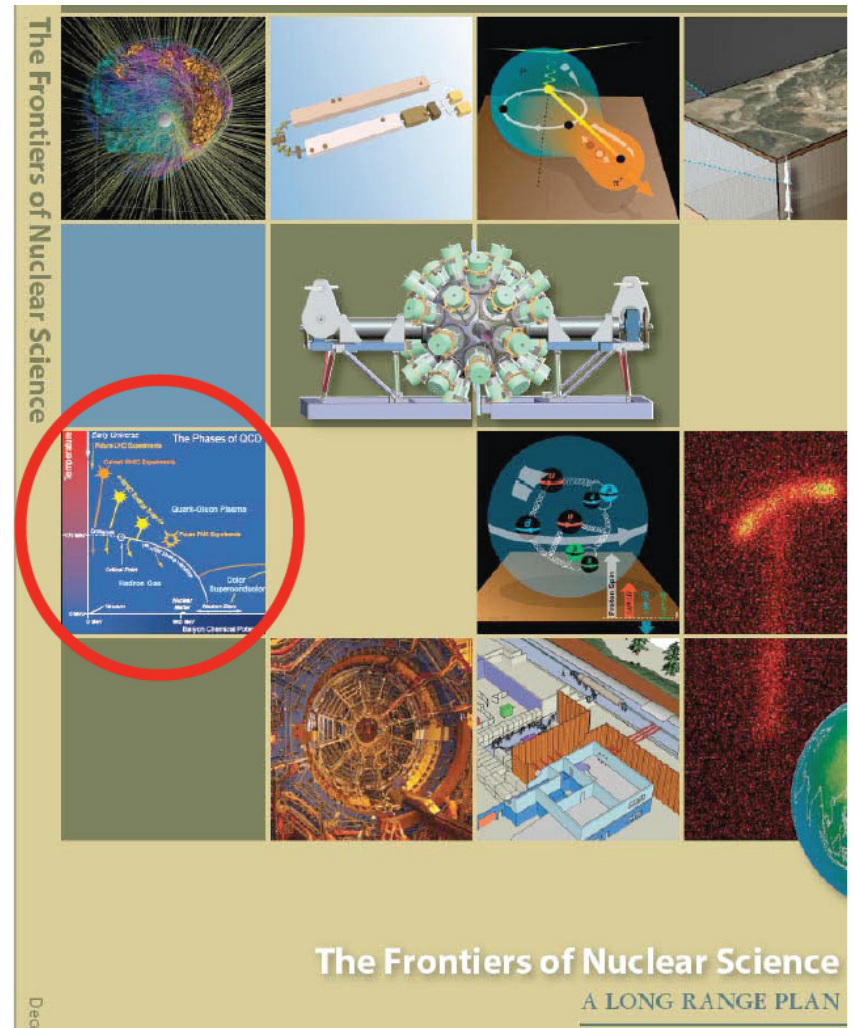
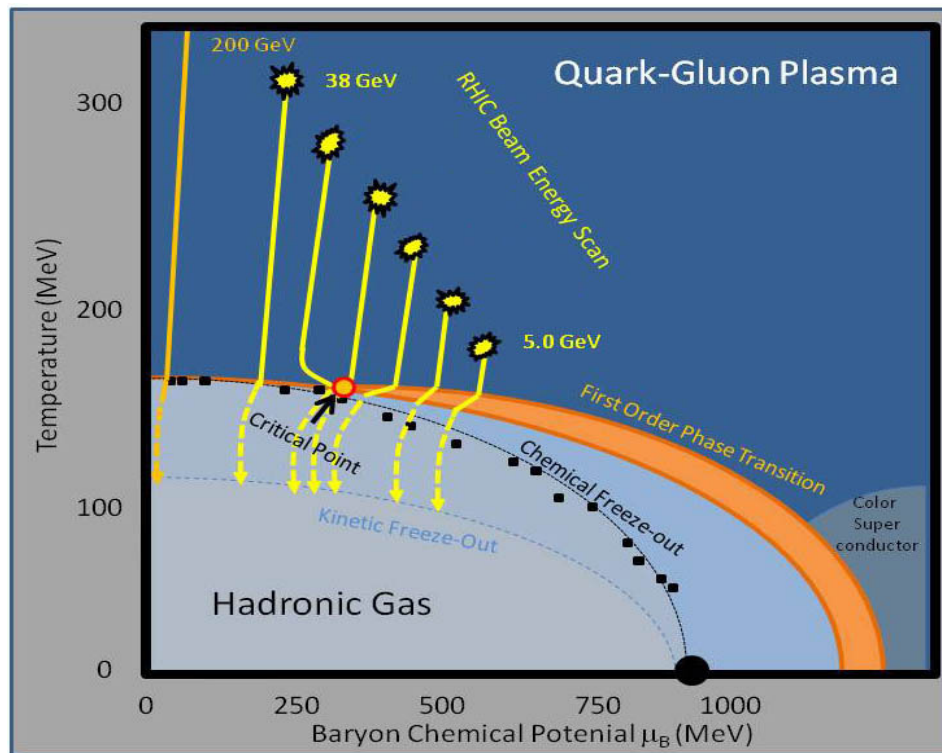
Details can be
found in White Paper
to be distributed shortly.

Low-energy RHIC physics program

4

There is substantial and growing interest in RHIC heavy ion collisions with c. m. energy in the range $\sqrt{s_{NN}} = 5\text{-}50\text{ GeV}/n$

Start of RHIC energy scan:
this coming 2010 run



Low-energy RHIC operation

5

- Present injection of Au ions in RHIC is at $\gamma=10.5$

RIKEN workshop (BNL, March 9-10, 2006):

“Can we discover the QCD critical point at RHIC?”

Suggested energy scan:

$\sqrt{s_{NN}} = 5, 6.3, 7.6, 8.6, 12, 16, 20 \text{ GeV/n}$

E-cooler: $E_{e,kinetic} = 0.9-3 \text{ MeV}$

0.9-2 MeV cooler

Three test runs were done in 2006, 2007, 2008 at low-energies in RHIC (T. Satogata et al., PAC07; PAC08; CPOD09).

Luminosity projections are low for the lowest energy points of interest. However, significant luminosity improvement can be provided with electron cooling applied directly in RHIC at low energies

Recently, there was some discussion about a possibility to extend cooling up to RHIC injection energy (4.9 MeV cooler).

Electron Cooler

6

Present baseline option:

Recycler's Pelletron (FNAL) – 6MV electrostatic electron accelerator

(main components: 1) pressure vessel 2) high-voltage insulating support structure 3) charging system 4) accelerating/decelerating tubes)

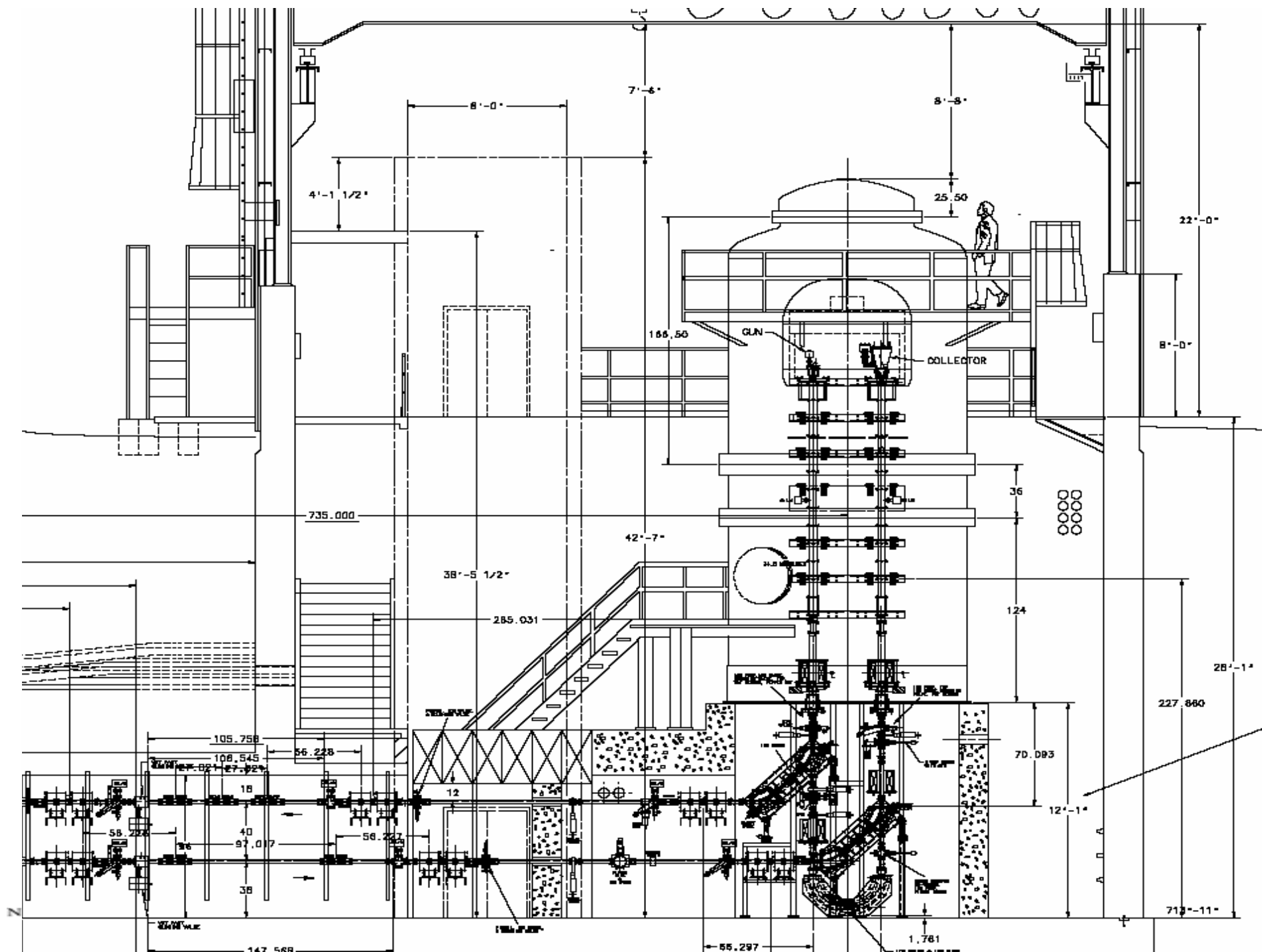
Covers full range of interest: 0.9-5MeV

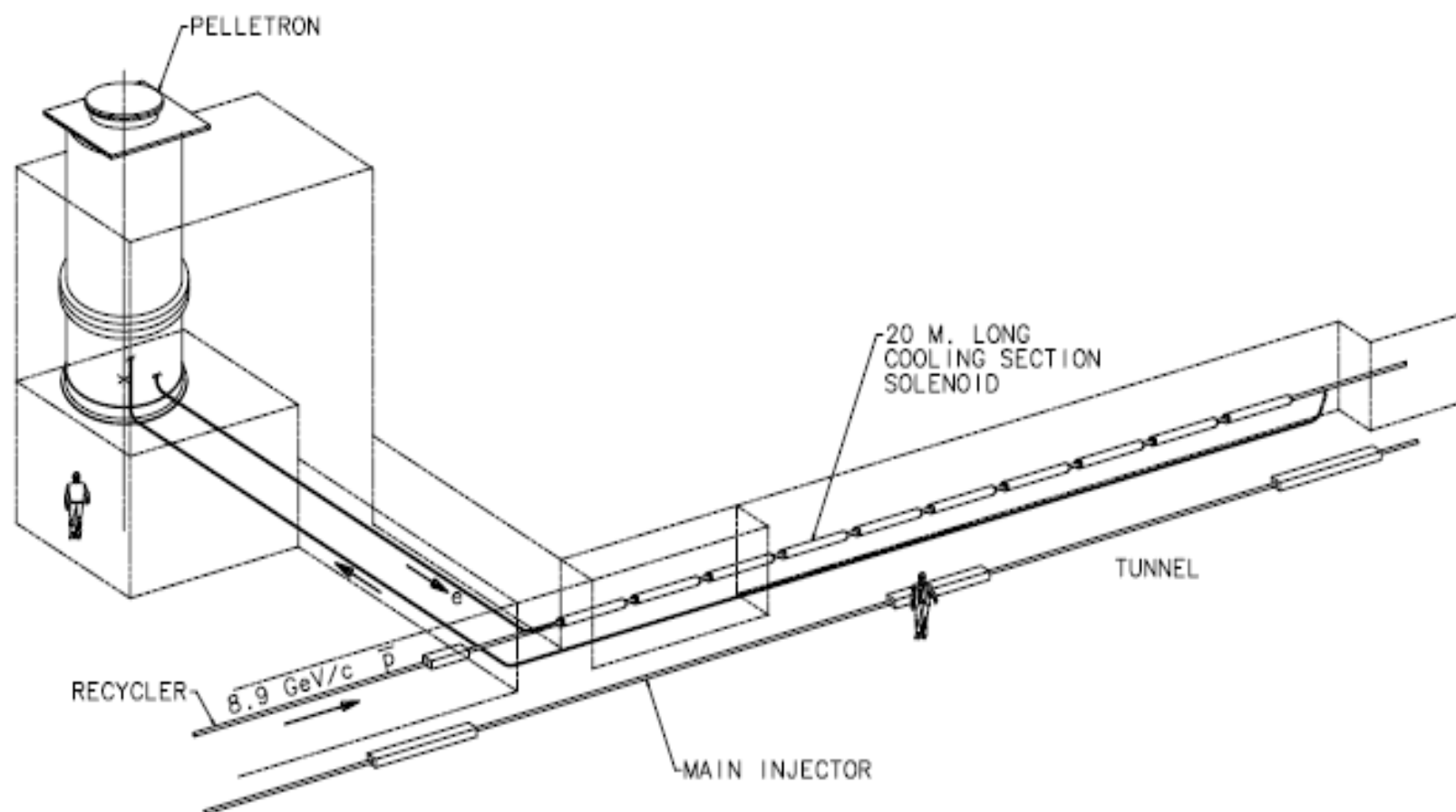
Possible timeline:

Based on assumption of Recycler's cooler availability at the end of 2011:

- 1) Transport and installation in RHIC in 2012.
- 2) Commissioning in 2012-13.
- 3) Ready for physics running by 2014.



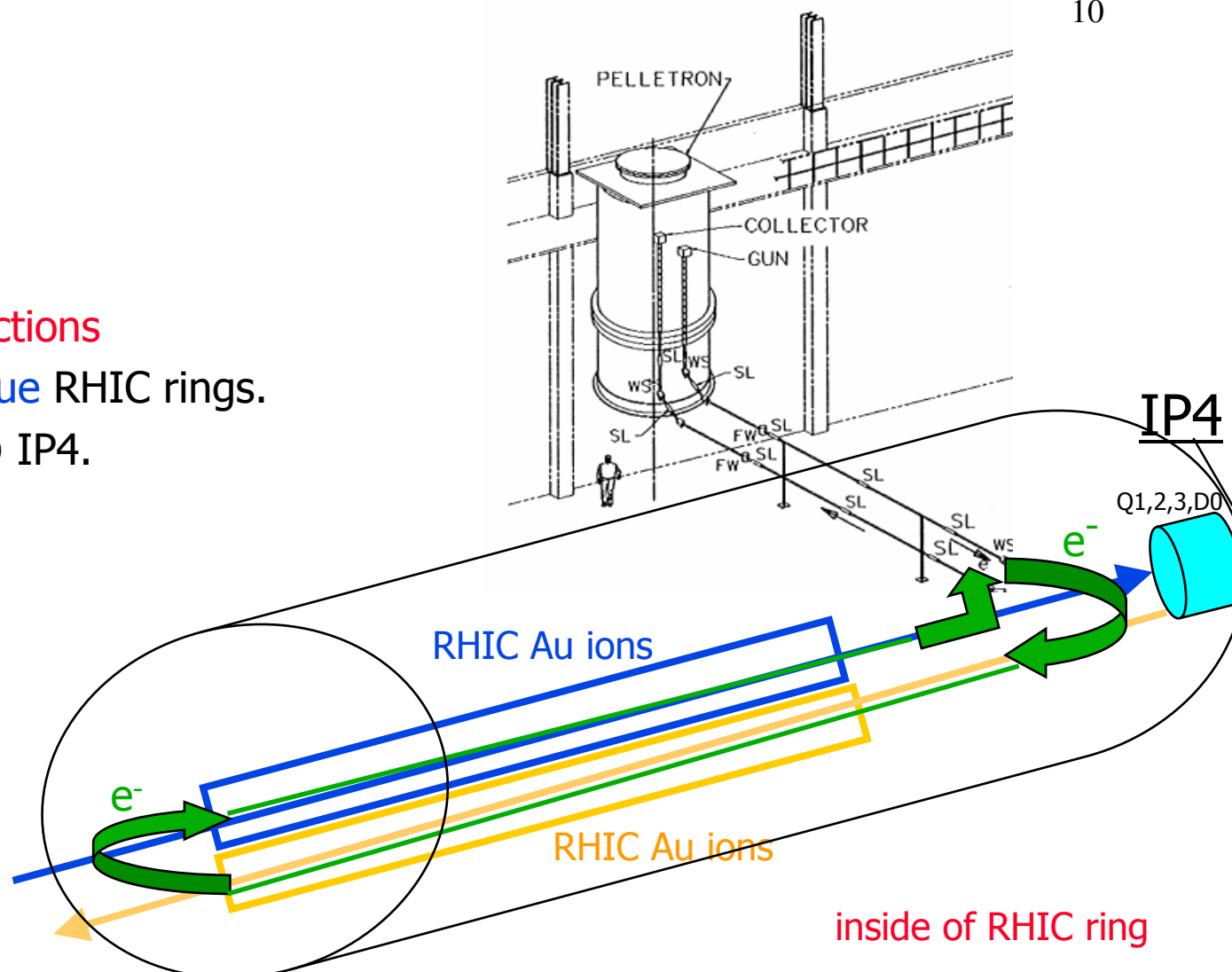


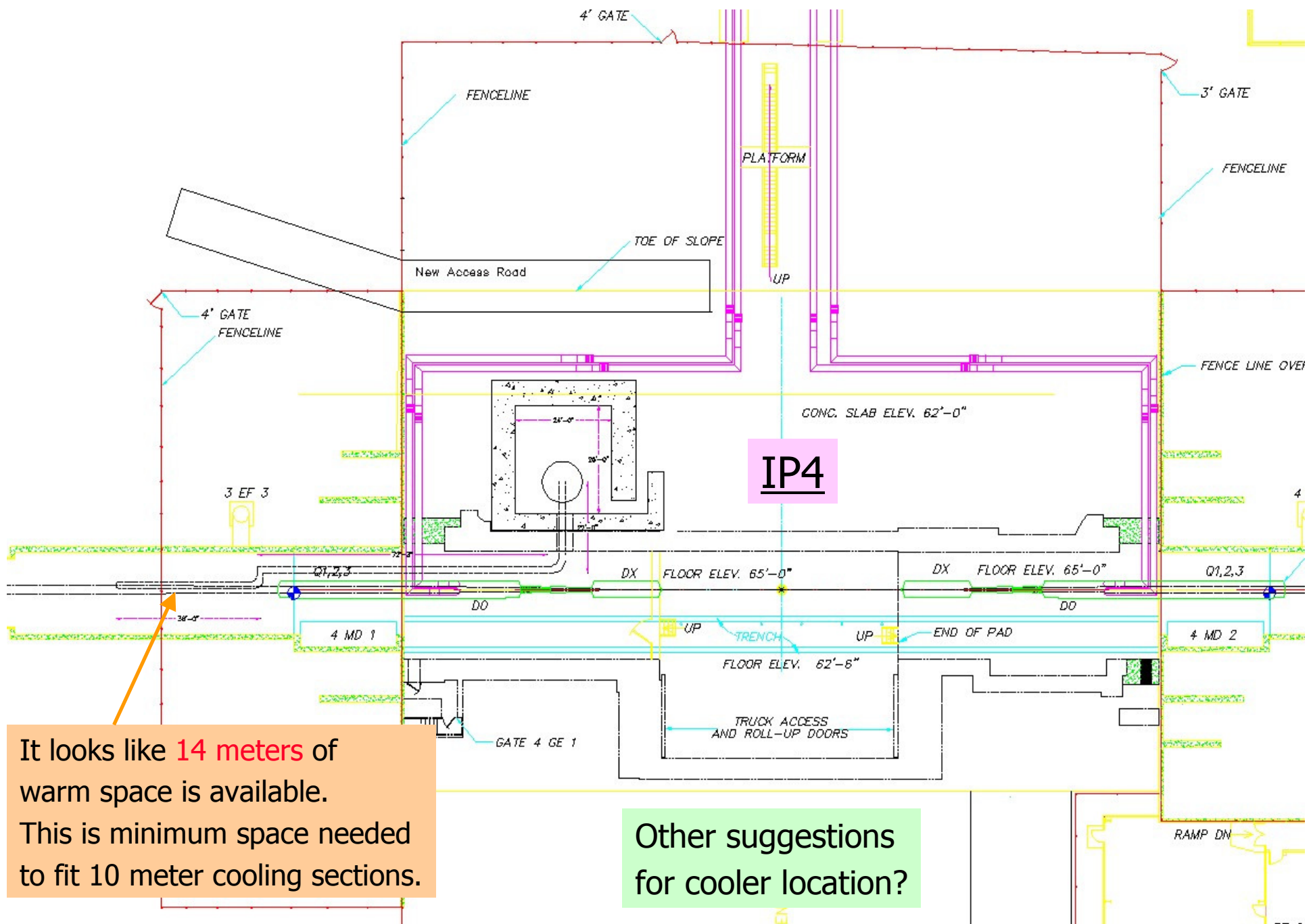


E-cooler schematics (@ RHIC)

10

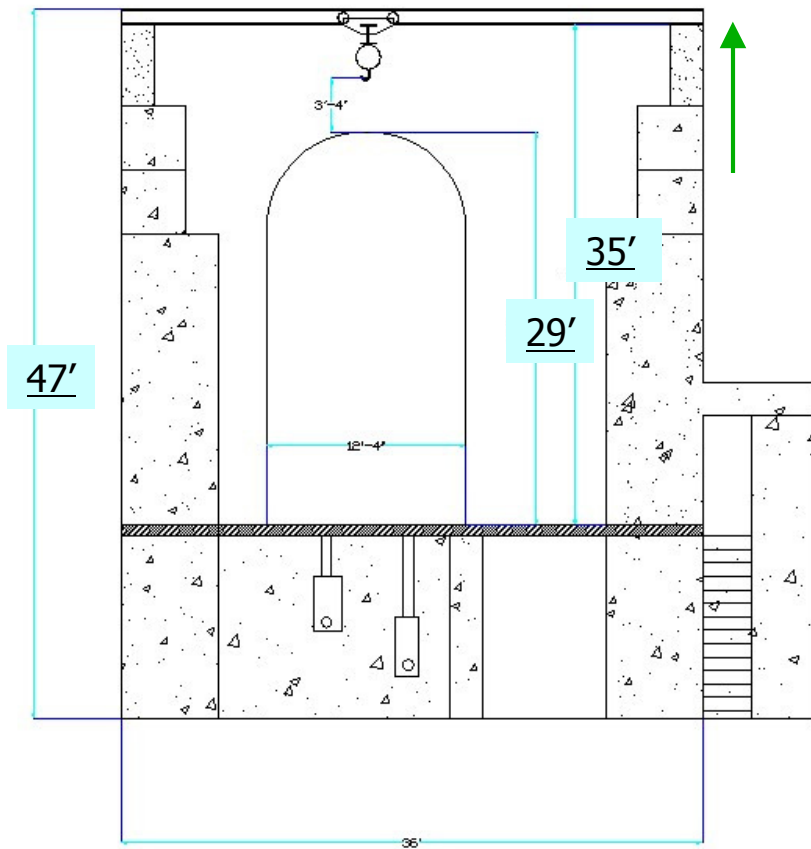
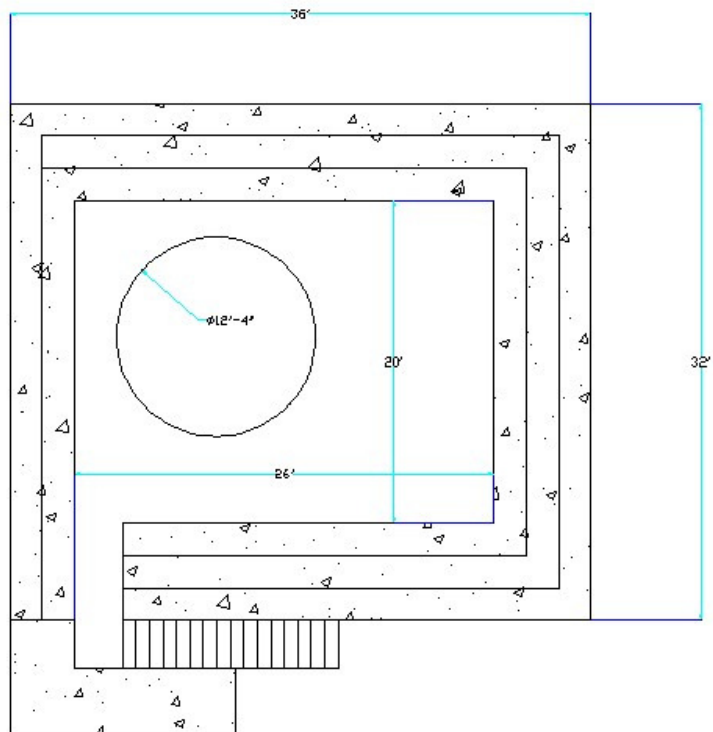
10 m cooling sections
in Yellow and Blue RHIC rings.
Warm section @ IP4.



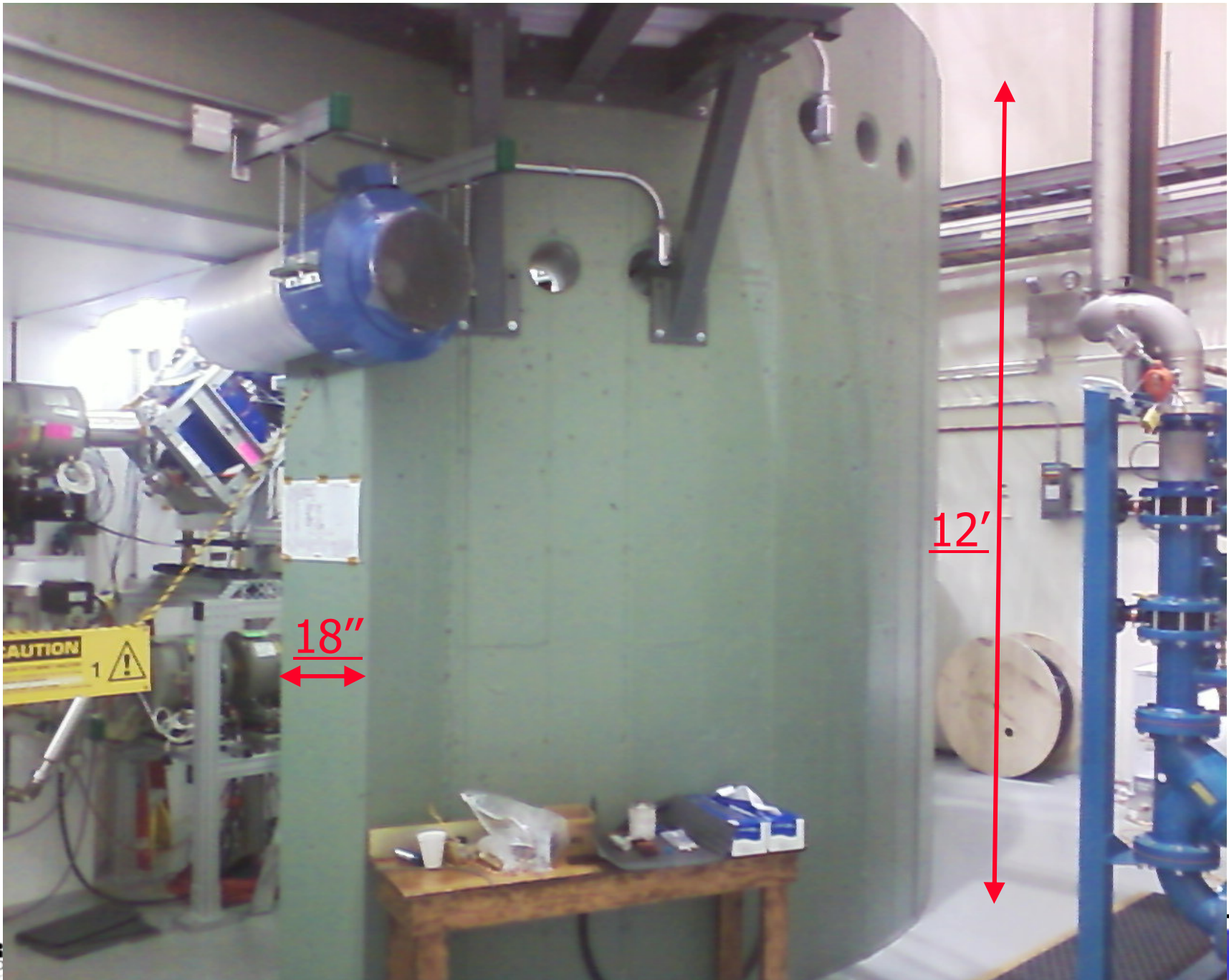


It looks like 14 meters of warm space is available. This is minimum space needed to fit 10 meter cooling sections.

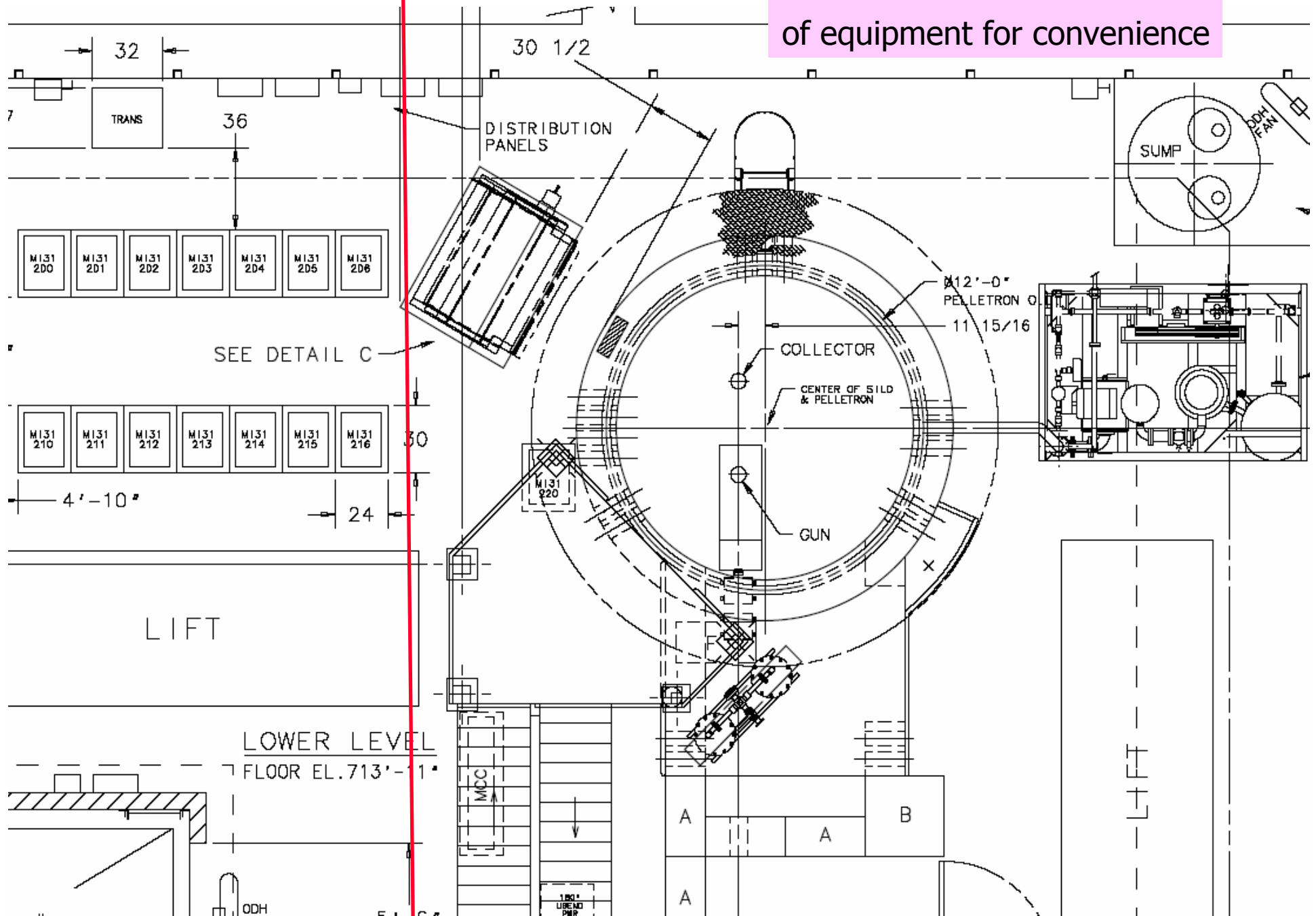
Other suggestions for cooler location?







30'x30' to fit most
of equipment for convenience



RHIC Electron Cooler parameters

17

Baseline approach:

“Non-magnetized” – means no strong magnetic field to guide electron beam and in cooling section

- 1) **“as is” - present FNAL’s set-up with small magnetic field on the cathode (100G) and in cooling section (100G) (+ undulators).**
- 2) **Zero magnetic field on the cathode and zero magnetic field in cooling section - short solenoids to counteract space-charge defocusing every 2 meter (+undulators).**

Electron kinetic energy, MeV	0.9-2.8 (4.9)
DC current, mA	50-100
RMS momentum spread	< 0.0004
RMS transverse angles, mrad	< 0.2
Undulator field B_u , G	3
Undulator period: λ_u , cm	8
Length of cooling section L_{cool} per ring, m	10

Disassembly & Transportation

Disassemble pelletron -labor and travel
Electrical disconnect of equipment & load centers
Rigging services to load
Transportation - 8 loads at 5000\$

952K

18

Site Preparation at BNL

Design & layout – architectural
Design & layout – electrical
Design & layout – mechanical

Prepare site access road & fence
Modify 4:00 wall, install blockhouse
Fabricate & install upper walls & roof
Insulate & seal blockhouse
Fabricate stairs, platforms and lifts
Install service building
Install SF6 tank foundation
Power to load centers
Lights & utility power
Blockhouse & service bldg AC
Compressed air extension
Fire Alarm & sprinklers
Network & communications
Sesmic consulting

1,174K

Results of preliminary
cost estimate

Installation

Assemble Pelletron in blockhouse (thru roof)
Place aux. equipment, stairs & platforms
Run tray to cooling section
Power equipment
Hookup Pelletron, e- transport & cooling section

562K (1,123K)

Design & fabricate undulators

Install undulators

not included

Design of magnets for additional bends

Fabricate U bend +6 -90 degree bends

Controls modifications & adaption

Vacuum modifications

Instrumentation modifications

1,172K

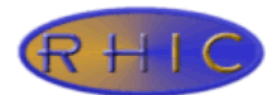
Power supplies for additional magnets

New power supplies (if needed)

Cooling section modifications (stands, etc.)

Total: 4.2M+controls+= under 5M

meeting: 10/22/09



FNAL visit (October 14-16, 2009)

19

FNAL's staff was extremely helpful in providing information needed. Specifically, the following areas were covered:

- **(Jerry Leibfritz, Linda Valerio)** – Architectural details of Pelletron Building and needed infrastructure; Pelletron transportation; work scope and planned work hours and timeline.
- **(Kermit Carlson)** – detailed description of electrical system, power supplies and controls
- **(Greg Saewert)** – electronics and protection equipment
- **(Roger Dixon)** – management issues and possible experiments
- **(Lionel Prost, Sasha Shemyakin)** – discussion of various physics and engineering questions.



Needed Recycler cooler modifications for RHIC

21

- As a result of the discussions, it became clear that significant **modifications of**
 - **electron cooling section**and
 - **beam transport** will be needed to adopt Recycler cooler for RHIC.Several engineering approaches were identified.
- However, in order to proceed with detailed engineering and site preparation at BNL, **decision about which approach to adopt (zero or non-zero magnetic field in cooling section)** should be made on a very short time scale of the order of a few month, with physics design finalized by the end of 2010.



If we go with **zero magnetic field** approach, then we do not change present 5" beam pipe in RHIC.
But this approach requires several other questions to be addressed.

If approach with **magnetic field**:
What is maximum allowable pipe diameter for baking to fit into solenoids?
 $R_{\text{solenoid}} = 6.9\text{cm}$?
Can we do $R = 3.75\text{cm}$ (3" pipe)?
 $R = 5\text{cm}$ (4" pipe)?



Experiments at FNAL which can help choosing an appropriate approach as well as explore Pelletron operation in a regime of parameters needed for RHIC were proposed:

1) 4.3MeV – present operational energy

Recirculation test without magnetic field on cathode and main cooling sections solenoids

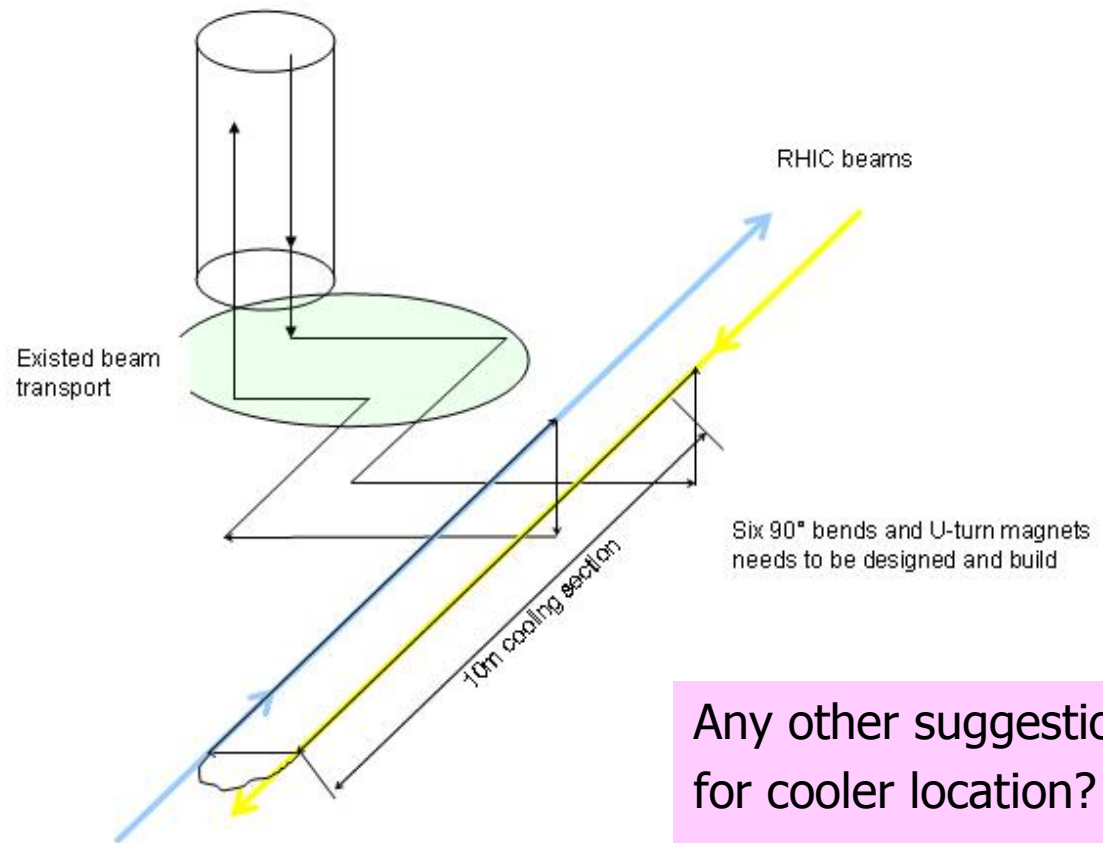
2) 1MeV recirculation without magnetic field

3) 4.3MeV, no magnetic field, cooling rate measurement

4) 1MeV recirculation with magnetic field

5) 4.9MeV recirculation.

Present schematics of beam transport for RHIC



Any other suggestions
for cooler location?

On top of RHIC tunnel?

- minimize number of needed bends
- careful design of bending magnets
- field stability and control in bends

1. (Assuming FNAL Recycler cooler will be available in October 2011, after Tevatron FY11 run):

Preliminary cost estimate of the project -	November 2009
Physics design complete	December 2010
Architectural design & layout	February 2010-February 2011
Electrical design & layout -	June 2010-June 2011
Mechanical design & layout -	June 2010-June 2011
Site preparation -	February 2011- March 2012 (14 month)
Recycler's cooler disassembly and transport	October 2011-February 2012 (5 month)
Electron cooler installation	March 2012 -January 2013 (10 month)
Commissioning	February-June 2013 (5 month)

Available for FY14 RHIC physics run - November 2013.

2. (Assuming Recycler's cooler is available only in October 2012, after Tevatron FY12 run):

Preliminary cost estimate of the project -	November 2009
Physics design complete	December 2010
Architectural design & layout complete -	August 2011
Electrical design & layout complete -	August 2011
Mechanical design & layout complete -	August 2011
Site preparation -	August 2011- December 2012 (17 month)
Recycler's cooler disassembly and transport	October 2012-January 2013 (4 month)
Electron cooler installation	February-September 2013 (8 month)
Commissioning	October-December 2013 (3 month)

Discussion with FNAL management (Pelletron availability – October-December 2011)

27

- It was also discussed, that move from feasibility study towards construction stage of the project and site preparation at BNL, will require spending significant funds on BNL side.
- Due to existing deadlines at BNL the construction stage of the project should start well in advance before availability of Pelletron for transfer (October 2011).
- As a result, a formal agreement between BNL and FNAL about Pelletron transfer will be required also before the actual date of Pelletron availability.
- It is expected that this question will be addressed by BNL and FNAL management – the sooner discussion starts the better.

Transferable and non-transferable items

28

Transferable - Pelletron with all equipment, transport lines, magnets, diagnostic, power supplies, controls chassis, electronics, etc.

Non-transferable - very minimal:

- Vacuum equipment (34 ion pumps & 9 gauges); 2 VME chassis
- 11 BPM's from cooling section will need to be replaced due small beam pipe aperture (only hardware), same for scrapers.
- Additional bending magnets will need to be designed and built; feedback system implemented.
- Perhaps, more stands or different stands

Message from FNAL

29

- **Recycler electron cooler is a well-working machine. It took years of R&D on various topics to make this machine well suitable for cooling.**
- **However, making this machine work in RHIC will be much more interesting (means “much more challenging”):**
 - **Recycler cooler** – 1) cools in a single ring 2) at fixed energy 3) with minimum bends in beam transport.
 - **In RHIC** – 1) will require cooling in 2 rings with the same electron beam 2) more bends and more complicated beam transport 3) everything from transport to cooling sections should be working “at best performance” for different energies 4) recombination 5) cooling in a collider

This requires a dedicated group of physicists and engineers (not 1-2 people) to evaluate and address all the possible issues.

Near-term goals

FY10:

30

- Start regular physics and engineering meetings
- Choose one design (with or without solenoids)
- Decide about undulators
- Design realistic beam transport
- Design appropriate bending magnets
- Address many physics and engineering questions
- Start architectural design
- Start electrical design
- Start mechanical design

Spring 2010 – collaboration (FNAL) review?

**Around December 2010: - formal agreement between BNL and FNAL;
decision how to proceed before spending AIP funds**

December 2010 – design review?

January 2011: start spending AIP funds (AIP funds in FY11, FY12, FY13)

Needed resources

Design phase (FY10):

Several physicists

Architectural layout & design: 1 person, 1 year, 50% of time ?

Electrical layout and design: 3 people, 10-20% of time each ?

Mechanical: 3 people, 10-20% of time each ?

Project engineer – 10% of time?

General department support (diagnostics, etc.)

AIP project phase (FY11-FY13):

Additional resources will be needed

Support from FNAL

Support from NEC